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A NEW SHORT BOREHOLE LOGGING TOOL

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Abstract: A new borehole surveying tool was used to log the deep borehole at Camp Century, Greenland in July 1992. This new 6.35 cm diameter instrument has a length of only 1 m, allowing it to pass through bends in the sometimes highly deformed boreholes. The fluid filled borehole was logged to within 35 m of bedrock, at a slant hole depth of 1350 m. The inclination approached or exceeded 30° several times in the lower portion of the borehole. A microprocessor controlled data acquisition package (DAP) measures an internal and external thermistor and two orthogonally mounted inclinometers. The pressure transducer, which also includes a temperature measurement, and the fluxgate compass have independent microprocessor systems which are multiplexed through the DAP. A coaxial cable supplies DC power from the surface to the logger and provides MODEM communications between the DAP and a personal computer on the surface where the data from the DAP and slant hole depth data from the winch are used to compute a directional survey of the borehole. The surface computer provides plots of temperature, fluid pressure, hole inclination and azimuth as a function of true vertical depth as the hole is being surveyed. A set of centering springs can be easily added at the ends of the logging tool for use in boreholes where the inclination is less than 1 degree.

1. Introduction

The deep borehole at Camp Century Greenland was logged in 1966, 1967, 1969 and 1989 (GUNDESTRUP *et al.*, 1993). The 1989 logging showed that a new short logging tool must be made to probe beyond the sharp bend at a depth of 1195 m, the maximum depth of the 1989 survey. The 4.5 m long 1989 logging tool is described by HANSEN *et al.* (1989).

A new short logger was constructed and used to survey the Camp Century borehole in July 1992 to a depth of 1350 m, passing through inclinations in excess of 30°.

2. Logger Description

Figure 1 shows the new logger which has a length of 1 m, a diameter of 6.35 cm and weighs 22.5 kg in air. There are transducers to measure the inclination of the borehole, the direction in which it is inclined, the pressure of the borehole fluid, and the temperature.

The inclination is measured by a pair of Columbia Model SA-120 RNP accelerometers with a range of 0.5 g (30°). Direction is measured by a KVH C-100 microprocessor controlled fluxgate compass. The fluid pressure is measured by a quartz sensor (Paroscientific Model 46K-161) with its own microprocessor. The temperature is measured with a thermistor (Fenwal GB32P2) mounted on the exterior bottom of the tool. Figure 2 shows how these sensors and their microprocessors connect to a data acquisition package (DAP) similar to an earlier version (KELTY and HANSEN, 1989). The logger is powered through the supporting coaxial cable which is also used for data communication.

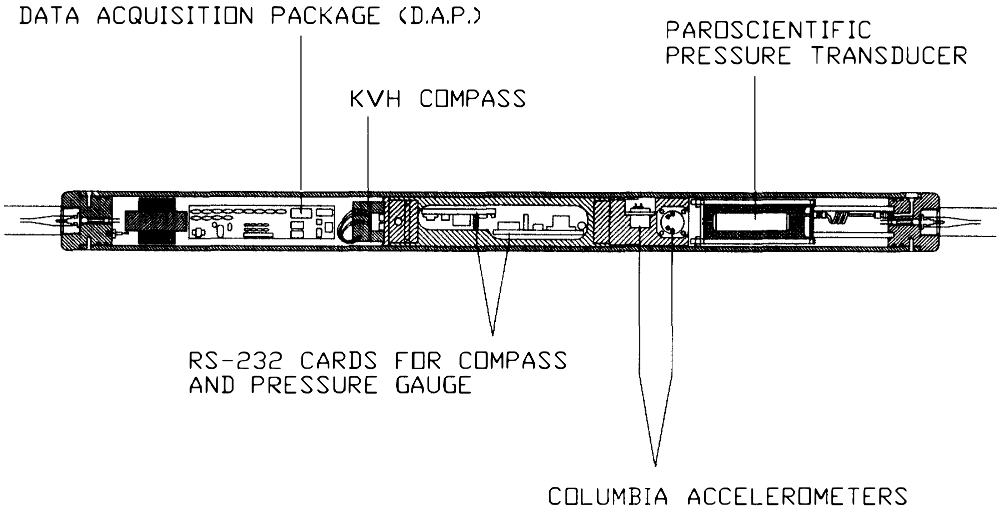

Fig. 1. Short borehole logger.

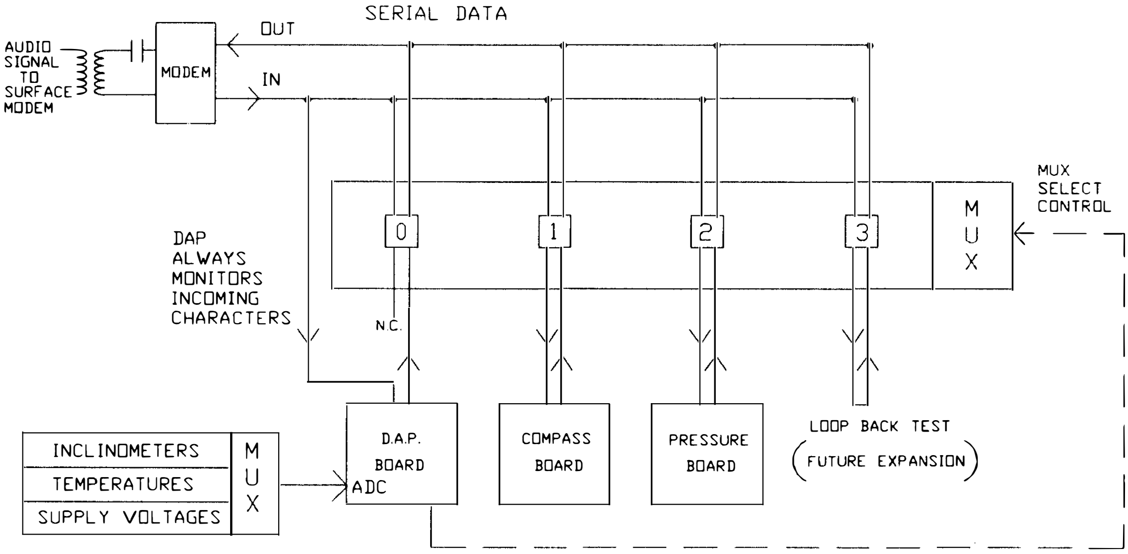

Fig. 2. Block diagram of DAP interconnections.

The power for the logger transducers is provided by DC to DC voltage converter modules. The input to these power converters is held at 12 V DC by a zener diode threaded into the upper end cap for heat sinking. Three converters supply +15, −15, and 5 V DC at about 2 W maximum each. The logger requires about 6 W plus the cable loss from a surface supply. The cable loss is significant. The surface supply provides 0.5 A at up to 150 V.

Having three microprocessors in the logger requires sharing the communications line to the surface computer. Figure 3 shows how the DAP controls a multiplexer (MUX) that allows the pressure board, the compass board, or the DAP to be "on line" to the surface through a MODEM. The DAP input line is always watching the incoming characters from the surface as the DAP is in control of the MUX. No MUX is required at the surface as all of the microprocessor boards are set to the same baud rate of 300 bits per second (the particular MODEM rate used) and only one of the processor boards can send data through the MUX at any given time. An ASCII character not used by either the compass or the pressure transducer is the character "@". When the character "p" is sent to the DAP, the pressure board serial lines connect via the MUX to the MODEM. To get back to the DAP, the character "@" is sent. The character "c" to the DAP switches the MUX over to the compass microprocessor board. Again, to return to the DAP, send an ASCII "@" character and the MUX switches back to the DAP. The DAP is always monitoring the incoming

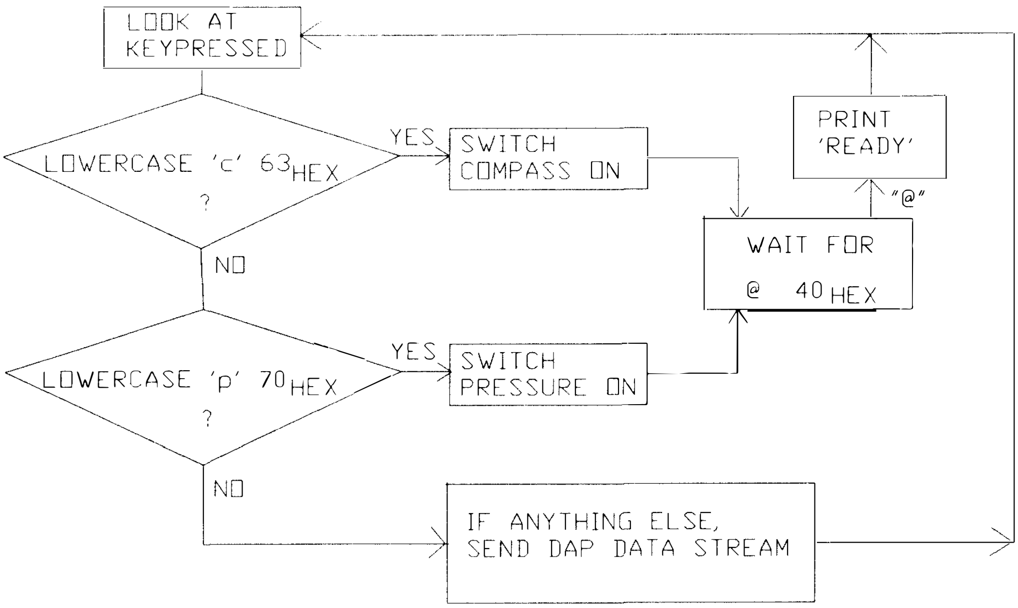

Fig. 3. DAP firmware flow for serial communications MUX control.

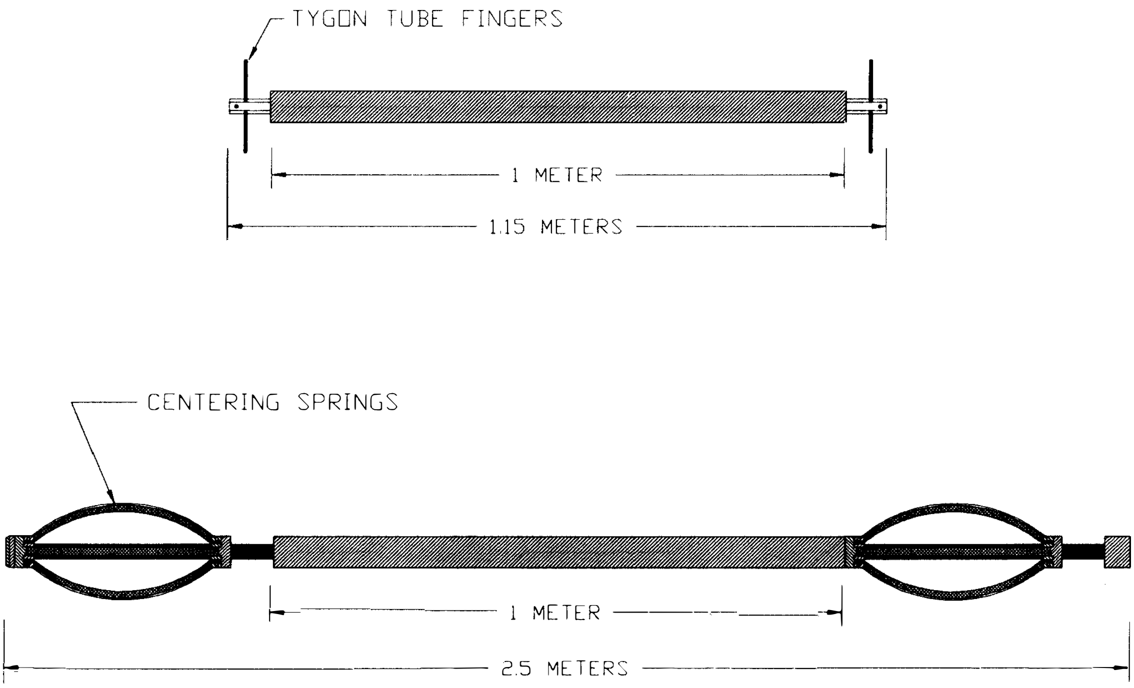

Fig. 4. The short logger with centering springs.

ASCII data, but only acts to change the MUX for characters "c" or "p" and only the character "@" switches the MUX lines back to the DAP for other data processing. The DAP firmware ignores other parameters used by the compass and pressure boards. Thus, only one processor is actively communicating back to the surface through the 300 BAUD MODEM, while the DAP monitors all of the incoming communications to control which processor multiplexes through the logger MODEM to the surface computer.

Prior experience has shown the need for a longer length logger with centering springs to measure the very small changes in inclination that occur over time in the upper part of nearly vertical boreholes. Figure 4 shows how the length extends to 2.5 m with centering springs.

The short logger is not centered in the borehole. Gravity and flexible TYGON tube fingers keep it pressed against the hole wall as shown in Fig. 5.

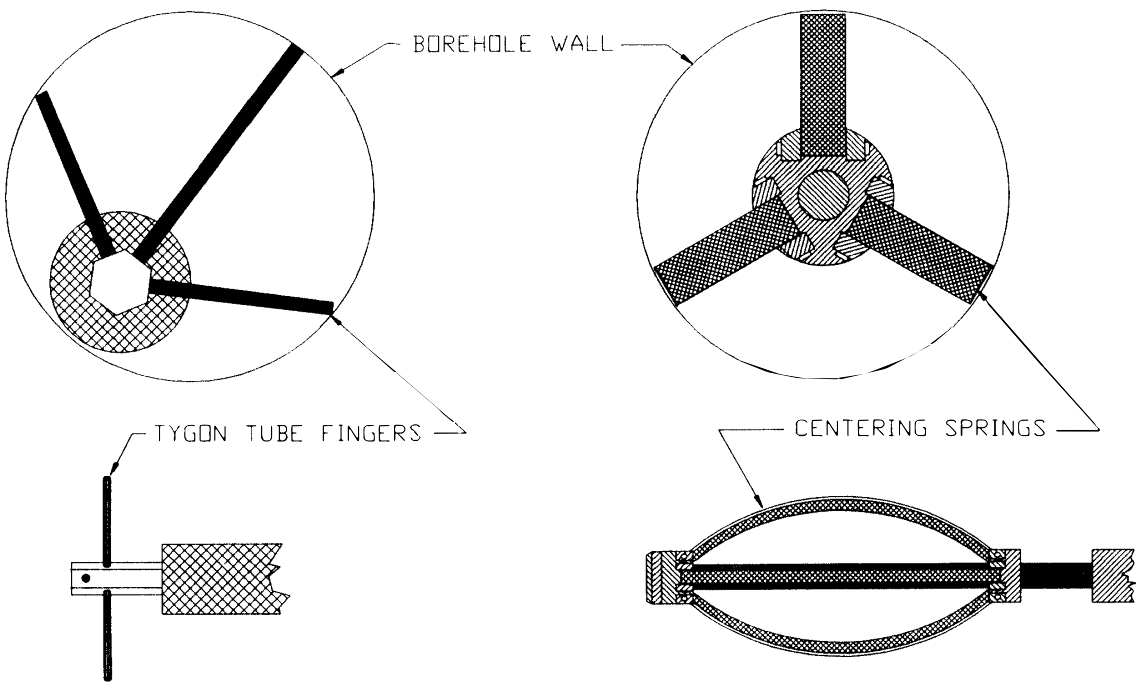

Fig. 5. Logger in borehole.

3. Data

Figure 6 shows the pressure in the borehole fluid as a function of depth. The density of the fluid is quite constant at 932 kg/m^3, slightly greater than the density of ice. The fluid level is 54 m below the surface so the fluid pressure is nearly equal to the overburden pressure at the bottom of the hole.

Figure 7 shows the inclination measured in 1992. Figure 8 is an expanded view at depths greater than 1100 m. It includes the 1989 data to a depth of 1195 m, the maximum depth reached in that year. The solid curve is down hole in 2.5 m steps; the dashed curve is up hole in 1 m steps.

Azimuth readings are meaningless at inclinations less than one half degree (HANSEN *et*

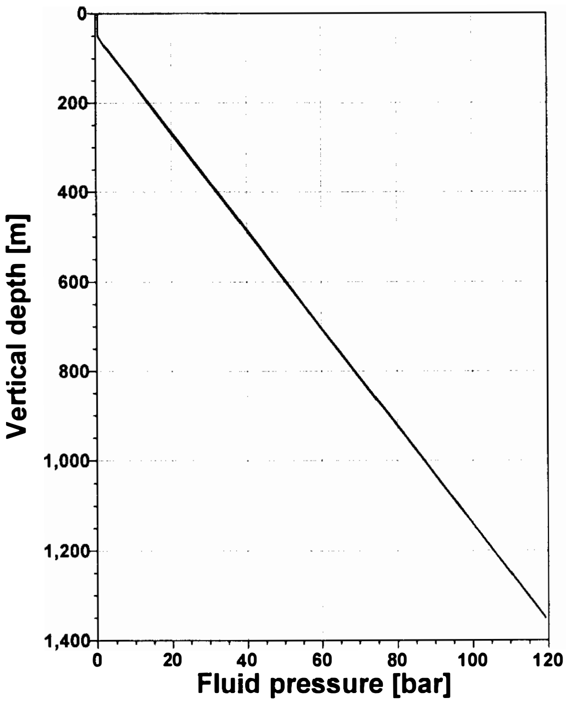

Fig. 6. Hole pressure vs. depth.

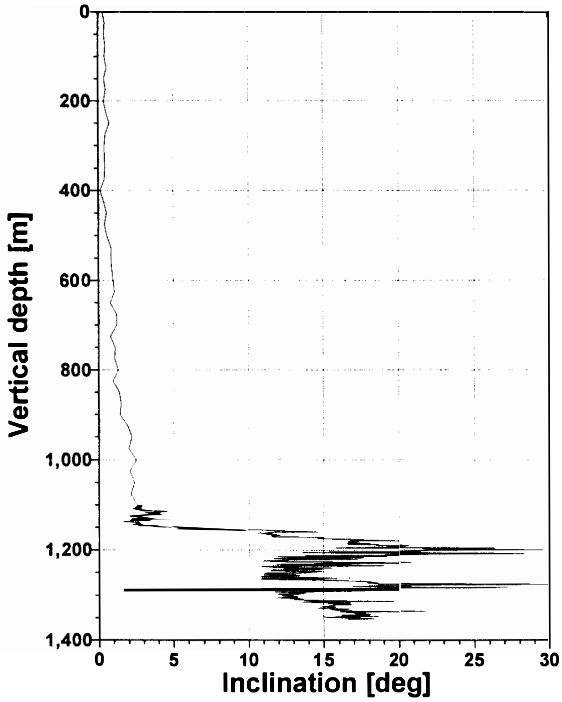

Fig. 7. Inclination vs. depth of the Camp Century borehole.

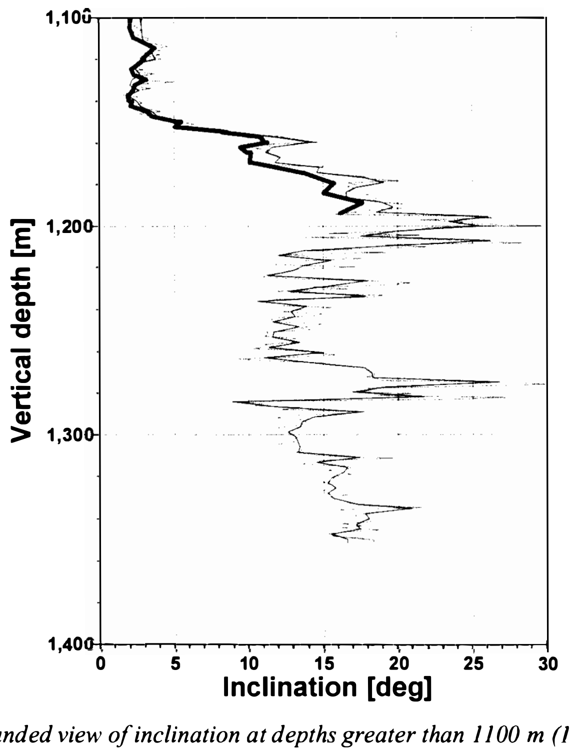

Fig. 8. Expanded view of inclination at depths greater than 1100 m (1989 and 1992 data).

al., 1989). The KVH sensor has a tilt range of 16 degrees, according to the manufacturer. However, the unit in the logger functions at inclinations up to at least 20 degrees. Azimuth data at inclinations in excess of 20 degrees may not be meaningful.

Acknowledgments

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